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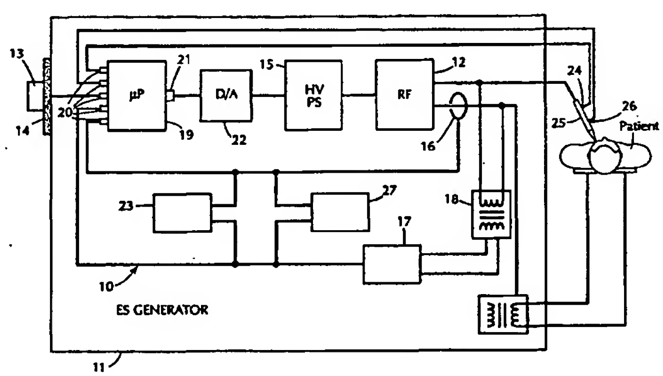

(57) Abstract

A power control system for an electrosurgical generator (11) will control the output power to desired levels. The power control system uses a simple closed-loop control algorithm. Sensors in the electrosurgical generator (11) will monitor changes in output current and output voltage. There may also be sensors to monitor changes in the temperature of the electrosurgical tool, mechanical strain in the electrosurgical tool, or phase shift between output voltage and output current. A microprocessor (19) in the electrosurgical generator (11) is connected to the sensors and repetitively compares the sensed values against their respective threshold values. The threshold values are computed by the microprocessor (19) based on the desired output power, or other desired tissue effects. The microprocessor (19) also has an output to control an adjustable high voltage power supply (15) in the electrosurgical generator (11). The microprocessor (19) will adjust the high voltage power supply (15) to maintain all sensed values below their respective threshold values. The threshold values are computed by the microprocessor (19) based on the desired output power, or other desired tissue effects. The threshold values may also be computed as a function of the impedance of the output load on the electrosurgical generator (11).

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POWER CONTROL FOR AN ELECTROSURGICAL GENERATOR

Related applications incorporated herein and made a part hereof by reference were filed with the United States Patent and Trademark Office on the same date, as follows:

"Control Apparatus for Electrosurgical Generator Power Output," U.S.S.N. 08/468,950; PC8827;

"A Control System for Neurosurgery," U.S.S.N. 08/470,533; PC9162;

"Exit Spark Control for an Electrosurgical Generator," U.S.S.N. 08/479,424; PC9217;

"Digital Waveform Generation for Electrosurgical Generators," U.S.S.N. 08/471,344; PC9210.

1. <u>Field of the Invention</u> This invention pertains to a power control system and its method of use in an electrosurgical generator, and more specifically to a control system for maintaining a desired level of electrosurgical power which is delivered to a patient.

2. <u>Background of the Disclosure</u> An electrosurgical generator is used in surgical procedures to deliver electrical power to the tissue of a patient. An electrosurgical generator includes a radio frequency generator and its controls. When an electrode is connected to the generator, the electrode can be used for cutting or coagulating the tissue of a patient with the high frequency electrical energy. The electrical energy has its waveform shaped to enhance its ability to cut or coagulate tissue. Different waveforms correspond to different modes of operation in the generator, and each mode gives the surgeon various operating advantages.

An electrosurgical generator can be used to cut and/or coagulate the tissue of a patient. A surgeon can easily select and change the different modes of operation as the surgical procedure progresses. In each mode of operation, it is important to regulate the electrosurgical power delivered to the patient to achieve the desired surgical effect. Applying more electrosurgical power than necessary results in tissue destruction and prolongs healing. Applying less than the desired amount of electrosurgical power inhibits the surgical procedure. It is desirable to control the output energy from the electrosurgical generator for the type of tissue being treated.

Different types of tissues will be encountered as the surgical procedure progresses and each unique tissue requires more or less power as a function of

frequently changing tissue impedance. Even the same tissue will present a different load impedance as the tissue is desiccated. The position and size of the electrosurgical tool will also effect the load.

Two conventional types of power regulation are used in commercial electrosurgical generators. The most common type controls the DC power supply of the generator by limiting the amount of power provided from the AC mains to which the generator is connected. A feedback control loop regulates output voltage by comparing a desired voltage with the output voltage supplied by the power supply. Another type of power regulation in commercial electrosurgical generators controls the gain of the high-frequency or radio frequency amplifier. An analogue feedback control loop compares the output power supplied from the RF amplifier for adjustment to a desired power level. The output is adjusted accordingly but generators commonly in use do not digitally measure RF output power delivered to the load and thereafter regulate accordingly. Usually, the generators are run open loop, i.e. without feedback. Generators that have feedback control are typically designed to hold a constant output voltage, and not to hold a constant output power for monopolar operation.

Specifically, U.S. Patents 3,964,487; 3,980,085; 4,188,927 and 4,092,986 have circuitry to reduce the output current in accordance with increasing load impedance. In those patents, constant voltage output is maintained and the current is decreased with increasing load impedance. Similarly, U.S. Patent 4,126,137 controls the power amplifier of the electrosurgical unit in accord with a non linear compensation circuit applied to a feedback signal derived from a comparison of the power level reference signal and the mathematical product of two signals including sensed current and voltage in the unit. U.S. Patent 4,658,819 discloses an electrosurgical generator which has means for decreasing the output power with increasing patient impedance.

Known types of radio frequency power regulation have achieved moderate success but certain undesirable characteristics are associated with each. One undesirable characteristic involves the response time for regulation. The impedance of the different tissues encountered during the surgical procedure can fluctuate substantially. In moving from a high impedance tissue to a low impedance tissue, the low impedance tissue may be needlessly destroyed or damaged before the

electrosurgical generator can reduce its output power to a level compatible with the lower impedance of the tissue. Similarly, when a high impedance tissue is encountered, the output power from the generator may be momentarily inadequate to create or continue the precise surgical effect desired by the surgeon. Wherefore, execution of the surgical procedure becomes difficult or impossible. Recognizing this problem is U.S. Patent 4,658,819 wherein the power delivered to the load is a function of the voltage from a DC supply and the load as measured by sensors of load voltage and current. A microprocessor controller digitizes the sensing signals and computes the load impedance and actual power being delivered to the load. The microprocessor controller accordingly repeats the measurement, calculation and correction process approximately every 20 milliseconds as long as the generator is operating.

Another radio frequency output power regulation related problem of available electrosurgical generators is open circuit flashing. Prior to the electrosurgical procedure commencement, no output power is supplied due to the open circuit condition. An open circuit condition also exists when the surgical instrument is withdrawn from the tissue. The regulation circuit attempts to compensate with maximum power delivery. When the active electrode is positioned an operative distance from the tissue, an arc of relatively high voltage ensues due to the maximum power delivery capability initiated by the power regulation circuit. Continual arcing is desired in the coagulation (fulguration) mode of operation but is otherwise undesirable. The power regulation circuit eventually reduces the excessive power but the initial arcing or flash may already have caused excessive tissue destruction. The flash and excessive tissue destruction can occur anytime the surgeon moves the active electrode toward or away from the tissue.

Open circuit or excessively high output impedance conditions increase the risks of alternate path burns to the patient. Alternate path burns occur when current flowing from the patient to some surrounding grounded conductive object, such as the surgical table, rather than returning to the electrosurgical generator through the patient return electrode. Reducing the output voltage under open circuit or high impedance conditions reduces the magnitude of and potential for radio frequency leakage currents.

Another radio frequency output power regulation related problem of

commercial electrosurgical generators relates to shorting the output terminals of the generator. A frequent though not recommended, technique of quickly determining whether an electrosurgical generator is operating is to simply short the two output electrodes and observe an electrical spark. A possible result of shorting is the destruction of the power supply in the generator. The generator quickly attempts to regulate from a high voltage open circuit condition to a short circuit low impedance condition. Due to the limitations on regulating speed, the electrical power components of the power supply are overdriven and can be quickly destroyed before adequate compensation can occur.

U.S. Patent 4,727,874 discloses an electrosurgical generator with a high frequency pulse width modulated feedback power control wherein each cycle of the generator is regulated in power content by modulating the width of the driving energy pulses. A disadvantage of this is the lack of a continuous sinusoidal output which is preferred for low radio frequency emissions and aids reduction of unwanted sparking. Instantaneous analysis of parts of the high frequency signals of the effects of impedance loads on the electrosurgical unit in real time is not possible. It is desirable to be able to examine a series of RF pulses and control the output with respect to the real time effect on tissue. Instantaneous corrections to the output are not possible; only changes over the average of the output pulses are feasible, see for example U.S. Patent 4,372,315. That patent discloses a circuit which measures impedances after delivering a set number of radio frequency pulses on a pulse burst by pulse burst basis. U.S. Patent 4,321,926 has a feedback system to control dosage but the impedance sensing is not on a real time basis.

Electrosurgical medical procedures require controllable and close regulation of the cutting and/or coagulating high frequency energy. The energy application must be limited to a desired surgical area in order that no damage be sustained by important structures or organs in the immediate vicinity of the cutting or coagulation, particularly in a laparoscopic operation. The tissue acts as a load which in electrical terms is considered as a variable impedance that is a function of the nature of the tissue being surgically treated. The load impedance has resistive, capacitive and inductive components and the energy pathways from the electrosurgical unit to the tissue similarly add resistive, capacitive and inductive components.

It would be preferred to instantaneously measure the variations of resistance,

inductance and capacitance and correct the output of the electrosurgical unit accordingly. This, however, is impossible to do but output parameters such as voltage, current and power of the electrosurgical unit may be measured and/or calculated. Similarly, selected operational parameters such as constant current, constant voltage, and constant power can be regulated but not on an instantaneous level since the frequency of the pulses is typically 500 kilohertz or higher. Circuits commonly in use for controlling the output of an electrosurgical unit are incapable of the response times necessary for a cycle-by-cycle basis.

Analogue measurement of output signals from instruments such as the electrosurgical unit are well known and in use because the physical world is primarily analogue and the processing of analogue signals in electronic circuits is accomplished easily. For example, amplification, filtering, frequency modulation, and the like are common electronic functions of circuits designed to handle analogue signals. Such signals tend to be continuous and therefore detectors of analogue signals have difficulty in recognizing discontinuities in the signal brought about by change.

Digital or discreet signals are those that change from one condition to another distinct condition. For example, an "on" or an "off" condition is easily measured since there is no continuity in the change from "on" to "off". The advantage in having to deal with only two conditions, i.e. the existence of either one or the other, limits measurement and has a definite benefit since no subjective interpretation need be applied. Numerous advantages are available with digitized signals including less sensitivity to change, pre-determined level of accuracy, better dynamic range, applicability to non-linear control, predictability and repeatability, insensitivity to environmental variations, replicatability, flexibility, multiplex ability, and economy.

Electrosurgical units put out analogue signals as their output. Processors or computers are arranged to consider digital signals and although analogue to digital signals conversion is necessary, the manner in which the conversion is made bears strongly on the accuracy and ability, i.e. response time, of the circuit used.

Described herein is an electrosurgical power control system which is responsive to load. The control system is neither found in the literature nor practiced in the field. The literature is of interest for its teachings of the knowledge of skilled artisans at the time of this invention.

SUMMARY OF THE INVENTION

A power control system and its method of use in an electrosurgical generator is disclosed. One of the advantages of this control system is that it is capable of closed loop control of the electrosurgical power delivered to a patient. Another advantage is that the closed loop control is based on a simple algorithm. Yet another advantage is that desirable output power characteristics can be achieved over a wide range of surgeon-selected power settings.

There are several parameters which are descriptive of the state of the electrosurgical generator. For example, one parameter is the output power of the generator. Other example parameters are the output current, output voltage, and the impedance of the load on the output.

There are also several parameters which are descriptive of the state of the electrodes which are attached to the electrosurgical generator. For example, one parameter may be the temperature of the electrodes. Another example may be the strain in the electrodes.

The time derivatives of any of the aforementioned parameters may also be parameters. For example, the time rate of change of output voltage may be a parameter. The time rate of change may be computed either by a sample-by-sample comparison, or may be computed by more advanced averaging and filtering methods.

An important advantage of the control system is that it can close the control loop on any of the parameters. This means that the output power can be adjusted automatically in response to the sensed behavior of any of the parameters. For example, if the output voltage started to rise above a desired threshold, the control system could make appropriate adjustments which will lower the output voltage.

A summary of operation of the control system follows. The output power of an electrosurgical generator is sent to an electrode from a radio-frequency output stage. An adjustable high voltage power supply in the generator can adjust the gain of the output stage, and thereby affect a change in the output power. The basis for the power control system is to use a microprocessor for adjusting the high voltage power supply.

The front panel of the electrosurgical generator has an indicator for the surgeon to use for setting the desired output power. The microprocessor will have an input for a signal from the front panel indicator. An algorithm in the

microprocessor will continuously output signals to adjust the high voltage power supply to achieve a desirable output power curve.

The microprocessor will also have inputs for signals from a number of sensors, such as a current sensor and a voltage sensor. Other information, such as power, may be computed from these sensors. The microprocessor will thus monitor the operating characteristics of the generator and also the load on the generator. Adjustments can be made in the high voltage power supply based on the sensed information and thereby insure that a desirable output power is maintained.

The algorithm in the microprocessor is designed to be simple so that it can be repetitively executed in short time period. The algorithm sets thresholds each for output power, output current, output voltage, and others. The thresholds are based in part on the input from the power setting indicator and also on the performance capabilities of the generator. The algorithm repetitively compares sensed and computed parameters against their respective thresholds. If no threshold is reached, the algorithm will upwardly increment the high voltage power supply. As soon as any threshold is reached, the algorithm will decrement the high voltage power supply.

The control system can easily accommodate multiple feedback paths. Some example feedback paths include the voltage and current delivered to the patient, the impedance of the patient load, the phase shift between the voltage and current, the temperature of the active electrode, and the drag or strain in the electrode used on the patient. Each feedback path can be used in the algorithm to control the electrosurgical power which is delivered to the patient.

The power control system is a "closed loop" control system. The feedback paths will respond to changes in the output of the electrosurgical generator, and then transmit that information to the control algorithm. The control algorithm will then adjust the power output based on the feedback information. Ultimately, the result is that the control system will continuously maintain the electrosurgical output power at a level very close to at least one of the thresholds.

The output power from the electrosurgical generator will vary according to the impedance of the load. The blood and tissue of a patient will initially present a very low impedance load, but will increase in impedance as the tissue becomes desiccated. Typically it will not be possible, nor even desirable, to maintain a

constant power output from the electrosurgical generator over the entire range of tissue impedance.

At the low end of the tissue impedance range, the power output will increase as impedance rises. Over a midrange portion of the tissue impedance range, the output power will be kept at a constant level which corresponds to the desired power setting indicator. At the high end of the tissue impedance range, the power output will decrease with a rise in impedance.

The power control system is capable of controlling the output power according to the impedance of the load. The algorithm will establish thresholds for the sensed or computed signals that correspond to desired output power characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic block diagram of a power control system for an electrosurgical generator.

Figure 2 is a representative graph of output power from an electrosurgical generator with a power control system.

DETAILED DESCRIPTION OF THE INVENTION

A power control system apparatus 10 for an electrosurgical generator 11 is described, as shown in Figure 1. The electrosurgical generator 11 has a radio-frequency output stage 12 for generating an output current and an output voltage. An adjustable power setting indicator 13 in the electrosurgical generator 11 is accessible to the surgeon for setting a desired level of electrosurgical power. The power setting indicator 13 may be in the form of a knob or switch on the front panel 14 of the generator 11.

An adjustable high voltage power supply 15 in the electrosurgical generator 11 is in electrical connection with the radio frequency (RF) output stage 12. The high voltage power supply 15 adjusts the gain in the output stage 12. In one embodiment, the high voltage power supply 15 can adjust between 0 and 200 volts. The RF output stage 12 is thereby adjustable to output between 0 and 10,000 volts. A voltage gain in the RF output stage 12 accounts for the difference in scale. The RF output stage 12 is designed to output an RF signal in the range of 200 kHz. to

1 MHz.

A current sensor 16 in the electrosurgical generator 11 is in electrical connection with the output current. In one embodiment, the current sensor 16 is connected on the output side of an output resonator, but in front of blocking capacitors. The current sensor 16 may be in the form of a sense coil.

A voltage sensor 17 in the electrosurgical generator 11 is in electrical connection with the output voltage. A transformer 18, with its primary coil across the active and return paths, will generate a signal which is proportional to the output voltage. In one embodiment, the transformer 18 is located on the input side of the blocking capacitors.

A microprocessor 19 is in the electrosurgical generator 11. In the preferred embodiment the microprocessor 19 is a Signetics/Phillips 87C562. The microprocessor 19 has a plurality of input ports 20 and at least one output port 21. The input ports 20 are in electrical connection with the sensed signals through analog-to-digital conversion means. The sensed signals include the output voltage sensor 17 and the output current sensor 16. In addition, the microprocessor has an input port 20 connected to the power setting indicator 13.

The microprocessor 19 will have an output port 21 in electrical connection with the adjustable high voltage power supply 15. The output port 21 will be a digital signal, and will typically have to be converted to an analog signal through a digital-to-analog converter 22. The microprocessor 19 will thereby have the capability to adjust the voltage of the high voltage power supply 15 through the output port 21.

An algorithm in the microprocessor 19 will use the input signals to monitor the operating characteristics of the generator 11. The algorithm is implemented in software for the microprocessor 19 and is designed to adjust the high voltage power supply 15 to maintain desirable output power characteristics. A representative curve for output power as a function of the load impedance is shown in Figure 2.

The algorithm sets thresholds for certain parameters. Parameters are values that describe the state of the electrosurgical generator 11 or the state of the load on the electrosurgical generator 11. Parameters are sensed internally in the electrosurgical generator 11, or else on the active electrode 25. Parameters may also be computed from other sensed values. For example, the impedance of the load

on the electrosurgical generator 11 may be computed from the output current and the output voltage.

In one embodiment the parameters are output power, output current, and output voltage. In another embodiment the parameters are temperature of the active electrode 25 and the derivative thereof. In yet another embodiment the parameters will include the derivatives of output power, output current, and output voltage.

The strain of the active electrode 25 may also be a parameter. The strain will indicate whether additional output power is needed to cut the tissue at the operative site. If the tissue is not being cut, the active electrode 25 will experience strain as the surgeon attempts to draw it across the tissue.

The thresholds are based in part on the input from the power setting indicator 13, which is set by the surgeon. The thresholds are also based in part on the design capabilities of the generator 11, so that the voltage and current outputs do not exceed safe design limits.

In the preferred embodiment, the algorithm repetitively compares the output power, output current, and output voltage against their respective thresholds. If no threshold has been reached, the algorithm will cause the microprocessor 19 to repetitively adjust the output port 21 to upwardly increment the high voltage power supply 15. If any threshold is reached, the algorithm will cause the microprocessor 19 to repetitively adjust the output port 21 to downwardly increment the high voltage power supply 15. This simple algorithm will insure that the output of the generator 11 will remain close to at least one of the thresholds.

The algorithm will raise or lower the output power in a manner that will insure that the lowest maximum threshold will not be exceeded. Therefore, by choosing thresholds in a strategic manner, the output power of the generator 11 can be controlled over the entire range of expected load impedance, as shown in Figure 2. When the impedance of the load is at the low end of the expected range, near point a in Figure 2, for example between 0 and 16 ohms, a constant current threshold will limit the output power. The algorithm will hold a constant output power over a midrange portion of the expected load impedance, point d in Figure 2, for example between 16 and 512 ohms. At the high range of the expected impedance, point c in Figure 2, for example above 512 ohms, a constant voltage threshold will limit the output power. In the preferred embodiment, the impedance ranges are defined by

powers of two, thereby simplifying the calculations in the microprocessor 19.

The thresholds for current, voltage, power, and other quantities are set by the algorithm based on the power setting indicator 13, and also based on the safe operating range of the generator 11. In one embodiment, the thresholds may change as a function of the load impedance.

In one embodiment, a separate power monitoring circuit 23 is included in the generator 11 so that the output power can be monitored independently from the algorithm in the microprocessor 19. The power monitoring circuit 23 has the capability of shutting off the output power in the event that a fault condition is detected. The power monitoring circuit 23 has its own separate microprocessor that is used to detect fault conditions. One example of a fault condition is where the output power substantially exceeds the power setting indicator 13.

In one embodiment, the algorithm will change the output port 21 by an amount proportional to a difference between the output current and the current threshold. Thus, a large difference between the output current and the current threshold will result in a large adjustment of the output port 21. This has the advantage of more rapidly increasing or decreasing the output power in response to a changed threshold. Similarly, the algorithm will change the output port 21 by an amount proportional to a difference between the output voltage and the voltage threshold, and by an amount proportional to a difference between the output power and the power threshold.

In an alternative embodiment, the algorithm will adjust the output port 21 by an amount proportional to a difference between one of the sensed parameters and the threshold for that sensed parameter. In another alternative embodiment, the algorithm will adjust the output port 21 by an amount proportional to an integral of a difference between one of the sensed parameters and the threshold for that sensed parameter. In yet another embodiment, the algorithm will adjust the output port 21 by an amount proportional to a derivative of a difference between one of the sensed parameters and the threshold for that sensed parameter.

The algorithm also repetitively computes impedance of the output load. In the preferred embodiment, the calculation is actually an approximation of the true impedance. The approximation allows the microprocessor 19 to cycle through the algorithm more quickly. The approximation of impedance is made by ignoring phase

information, and thus assuming that the impedance is very close to a true resistance. In one embodiment, the approximation is further simplified by inferring that the impedance is within a certain range, based on the relative magnitudes of the output voltage and the output current. For example, when the current is high relative to the voltage, the algorithm infers that the impedance is in the low range of 0 to 16 ohms. A further example would be where the output voltage is high relative to the output current, where the algorithm would infer that the impedance is in a high range greater than 512 ohms.

In one embodiment, a temperature sensor 24 is located on the active electrode 25. The microprocessor 19 has an input for signals which are derived from the temperature sensor 24. Further, the algorithm sets a threshold for the temperature signals and repetitively compares the temperature signals with a temperature threshold.

In another embodiment, a strain sensor 26 is located on the active electrode 25 and is in electrical connection with an input port 20 of the microprocessor 19. The algorithm sets a strain threshold and repetitively compares the strain sensor 26 with a strain threshold. In this configuration, output power will be increased when the surgeon is cutting tissue and the strain sensor 26 detects that cutting action is being mechanically resisted by the tissue.

In another embodiment, the algorithm repetitively computes a phase angle between the output voltage and the output current, and repetitively compares the phase angle with a phase threshold. In this embodiment, a separate phase detection circuit 27 is incorporated in the generator 11. The phase detection circuit 27 sends a signal to one of the input ports 20 of the microprocessor 19. The phase angle between the output voltage and the output current is indicative of the impedance of the output load. Therefore, as the phase angle increases, the algorithm adjusts according to the conditions for higher impedance.

A method for controlling output power in an electrosurgical generator 11 comprises the steps of: adjusting a power setting indicator 13 in the electrosurgical generator 11 to set a desired level of electrosurgical power; adjusting the radio-frequency output stage 12 with a high voltage power supply 15 that is in electrical connection with the radio-frequency output stage 12; sensing the output current with a current sensor 16; sensing the output voltage with a voltage sensor 17;

adjusting the high voltage power supply 15 with a microprocessor 19 in the electrosurgical generator 11; and executing an algorithm in the microprocessor 19. The algorithm has steps of setting thresholds each for output power, output current, and output voltage, where the thresholds are based in part on the input from the power setting indicator 13; repetitively comparing the output power, output current, and output voltage against their respective thresholds; repetitively adjusting the output port 21 to upwardly increment the high voltage power supply 15 whenever none of the thresholds has been reached; and repetitively adjusting the output port 21 to downwardly increment the high voltage power supply 15 whenever any of the thresholds has been reached.

What is claimed is:

1. An electrosurgical generator 11 used by a surgeon for applying electrosurgical power to the tissue or bodily fluids at the operative site of a patient, the electrosurgical generator 11 having one or more sensed parameters which indicate the state of the electrosurgical generator 11 and indicate the state of the tissue or bodily fluids at the operative site, the electrosurgical generator 11 comprising:

an adjustable power setting indicator 13 in the electrosurgical generator 11 which is accessible to the surgeon for setting a desired level of electrosurgical power;

a radio frequency output stage 12 in the electrosurgical generator 11 for generating an output current and an output voltage;

an adjustable high voltage power supply 15 in the electrosurgical generator 11 and in electrical connection with the radio frequency output stage 12;

a current sensor 16 in the electrosurgical generator 11 and electrically connected to receive the output current for producing a first signal proportional to the output current;

a voltage sensor 17 in the electrosurgical generator 11 and in electrical connection with the radio frequency output stage 12 for producing a second signal proportional to the output voltage;

a microprocessor 19 in the electrosurgical generator 11, the microprocessor 19 having a plurality of input ports 20 and at least one output port 21, wherein a first input port 20 is in electrical connection with the adjustable power setting indicator 13, a second input port 20 is in electrical connection to receive the first signal from the current sensor 16, a third input port 20 is in electrical connection to receive the second signal from the voltage sensor 17, and at least one output port 21 is in electrical connection with the adjustable high voltage power supply 15;

an algorithm in the microprocessor 19,

the algorithm providing thresholds each for the one or more sensed parameters, wherein the thresholds are provided based in part on the input from the adjustable power setting indicator 13,

the algorithm repetitively comparing the values of the one or more sensed parameters against their respective thresholds,

the algorithm repetitively adjusting the output port 21 to upwardly increment the high voltage power supply 15 whenever no threshold has been exceeded, and

the algorithm repetitively adjusting the output port 21 to downwardly increment the high voltage power supply 15 whenever any threshold has been exceeded.

2. The apparatus of Claim 1 wherein the microprocessor 19 also has a second algorithm in which the first signal is multiplied by the second signal to obtain a third signal which is proportional to output power, and the third signal is also one of the sensed parameters.

3. The apparatus of Claim 1 wherein the first signal from the current sensor 16 provides one of the sensed parameters.

4. The apparatus of Claim 1 wherein the second signal from the voltage sensor 17 provides one of the sensed parameters.

5. The apparatus of Claim 2 wherein the microprocessor 19 also has a third algorithm which computes a rate of change of the third signal, and the rate of change of the third signal is one of the sensed parameters.

6. The apparatus of Claim 1 wherein the microprocessor 19 also has a fourth algorithm which computes a rate of change of the first signal, and the rate of change of the first signal is one of the sensed parameters.

7. The apparatus of Claim 1 wherein the microprocessor 19 also has a fifth algorithm which computes a rate of change of the second signal, and the rate of change of the second signal is one of the sensed parameters.

8. The apparatus of Claim 1 wherein there is an impedance computing circuit in the electrosurgical generator 11 which computes the impedance of the tissue or bodily fluids at the operative site of the patient.

9. The apparatus of Claim 1 wherein the algorithm will adjust the output port 21 by an amount proportional to a difference between one of the sensed parameters and the threshold for that sensed parameter.

10. A power control method for an electrosurgical generator 11 used by a surgeon for applying electrosurgical power to the tissue of a patient at an operative site using an electrode, the electrosurgical generator 11 having a radio-frequency output stage 12 for generating an output current and an output voltage, the tissue

at the operative site presenting a output load on the generator 11, the output load having an impedance, the control method comprising the steps of:

adjusting a power setting indicator 13 in the electrosurgical generator 11 to set a desired level of electrosurgical power;

adjusting the radio-frequency output stage 12 with a high voltage power supply 15 that is in electrical connection with the radio-frequency output stage 12;

sensing the output current with a current sensor 16;

sensing the output voltage with a voltage sensor 17;

adjusting the high voltage power supply 15 with a microprocessor 19 in the electrosurgical generator 11; and

executing an algorithm in the microprocessor 19, the algorithm having steps of:

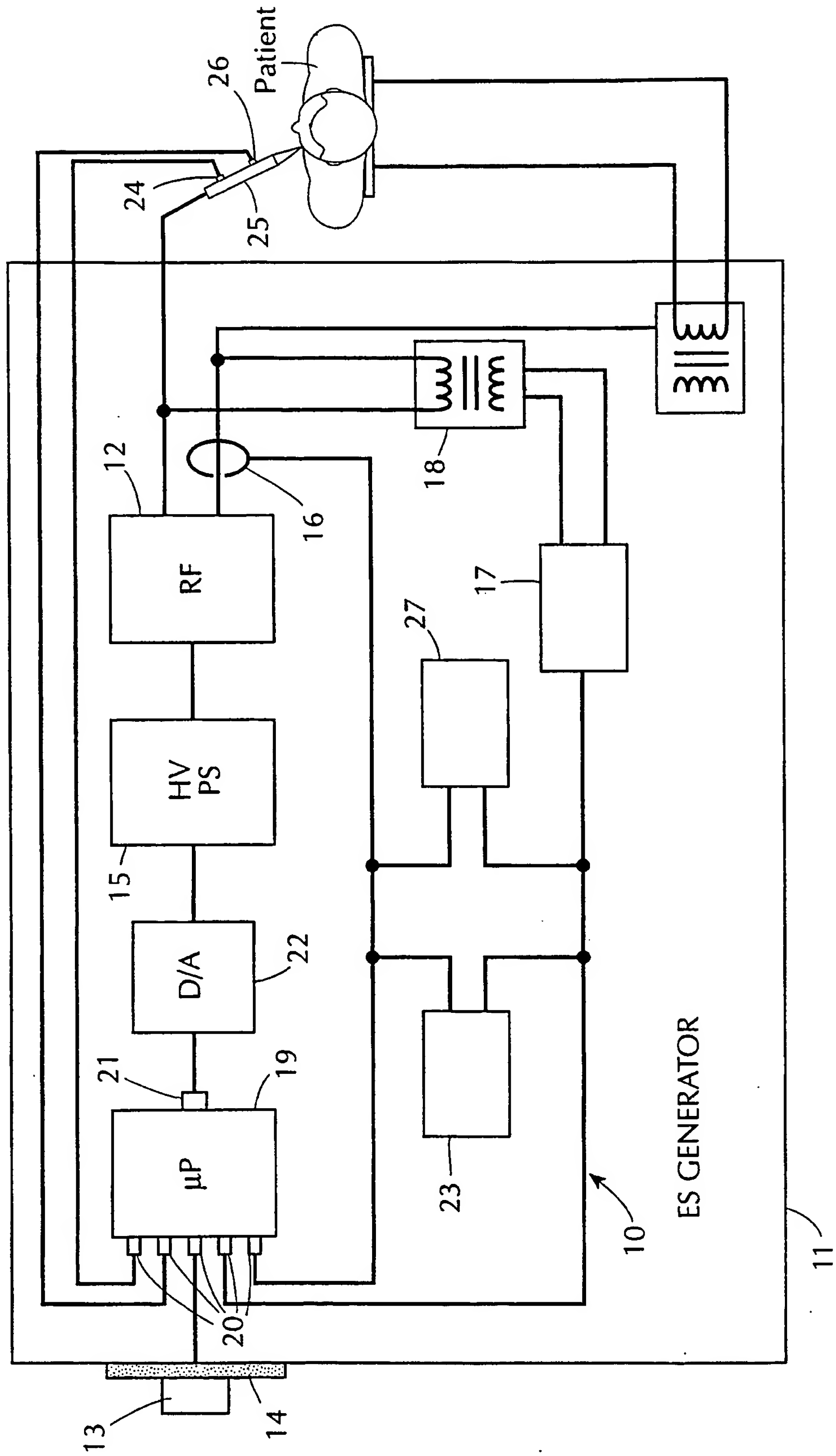
setting thresholds each for one or more sensed parameters, where the thresholds are based in part on the input from the power setting indicator 13,

repetitively comparing the sensed parameters against their respective thresholds,

repetitively adjusting the output port 21 to upwardly increment the high voltage power supply 15 whenever no threshold has been exceeded, and

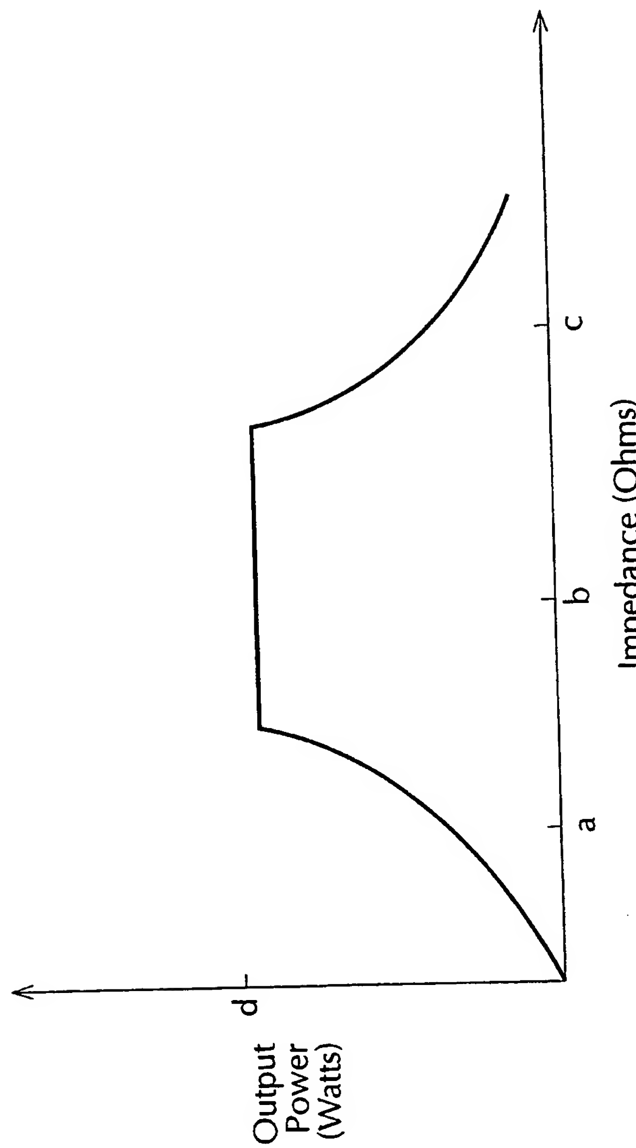
repetitively adjusting the output port 21 to downwardly increment the high voltage power supply 15 whenever any threshold has been exceeded.

FIG. 1


Patient
26
24
25
RF
12
16
18
HV
PS
15
D/A
22
μP
21
19
20
27
17
23
10
ES GENERATOR
11
13
14

2/2

FIG. 2



INTERNATIONAL SEARCH REPORT

In' l Application No
PCT/IB 96/00549

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B17/39

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE,A,38 30 193 (HUBMANN) 15 March 1990 see column 2, line 58 - column 3, line 9; figure 2 ---	1-6,8,10
Y	WO,A,94 10922 (EP TECHNOLOGIES) 26 May 1994 see page 12, line 6 - page 13, line 25 see page 25, line 27 - page 26, line 10 see page 24, line 3 - line 8 ---	1-6,8,10
A	WO,A,94 23659 (VALLEYLAB) 27 October 1994 see abstract see page 1 - page 7, line 7 ---	1
A,P	WO,A,95 25472 (VIDAMED) 28 September 1995 -----	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

2

Date of the actual completion of the international search	Date of mailing of the international search report
6 September 1996	13. 09. 96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Papone, F

INTERNATIONAL SEARCH REPORT

.tional application No.

PCT/IB 96/00549

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 10
because they relate to subject matter not required to be searched by this Authority, namely:
PCT Rule 39.1 (iv)

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searches without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

...ormation on patent family members

Inter ! Application No
PCT/IB 96/00549

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
DE-A-3830193	15-03-90	CH-A-	680702	30-10-92
WO-A-9410922	26-05-94	NONE		
WO-A-9423659	27-10-94	US-A-	5370645	06-12-94
		AU-B-	6289394	08-11-94
		CA-A-	2160017	27-10-94
		EP-A-	0695144	07-02-96
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		JP-T-	8504646	21-05-96
		NO-A-	954153	18-10-95
WO-A-9525472	28-09-95	US-A-	5484400	16-01-96
		US-A-	5542916	06-08-96
		AU-B-	2196595	09-10-95